PRECISION MEASUREMENT OF THE HIGGS BOSON MASS AND SEARCH FOR DILEPTON MASS RESONANCES IN H $\rightarrow 4\ell$ DECAYS USING THE CMS DETECTOR AT THE LHC

By

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A DISSERTATION PRESENTED TO THE GRADUATE SCHOOL
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This work is dedicated to the living and loving memory of Jacob Myhre.

ACKNOWLEDGEMENTS

Without so many two- and four-legged blessings along the way, I could never have made it to this point in my academic career. Thus, I begin by giving my endless gratitude to my high energy physics mentors, Professors Andrey Korytov and Guenkah Mitselmakher, for granting me this one-of-a-kind opportunity to do real *science* at CERN.

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To Big Tree who stood as a symbol of strength, beauty, and life for centuries before us. As Irma's wild whirring winds worsened, the cacophony of ripping roots resounded throughout the western corridor. There I stood in that frozen moment—awestruck, speechless—watching her *fall* helplessly towards the physics building. What could have been a catastrophe of cataclysmic proportions was instead a gentle grazing against the north windows of NPB where, there, she was gracefully laid to rest.

Finally, to Existence, for this unpredictable, unbelievable blip of an experience called Life.

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By

Jake Rosenzweig

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Chair: Andrey Korytov
Co-Chair: Guenakh Mitselmakher
Major: Physics

The mass of the Higgs boson is measured in the $H \rightarrow ZZ^* \rightarrow 4\ell$ ($\ell = e, \mu$) decay channel and is found to be $m_H = 125.38 \pm 0.11\,\text{GeV}$; the most precise measurement of m_H in the world to date. The data for the measurement were produced from proton-proton (pp) collisions at the Large Hadron Collider with a center-of-mass energy of 13 TeV during Run 2 (2016–2018), corresponding to an integrated luminosity of $137.1\,\text{fb}^{-1}$, and were collected by the Compact Muon Solenoid experiment. This measurement uses an improved analysis technique in which the final state muon tracks are constrained to originate from the primary pp vertex. Using data sets from the same run, a search for low-mass dilepton resonances in Higgs boson decays to the 4ℓ final state is also conducted. No significant deviation from the Standard Model prediction is observed.

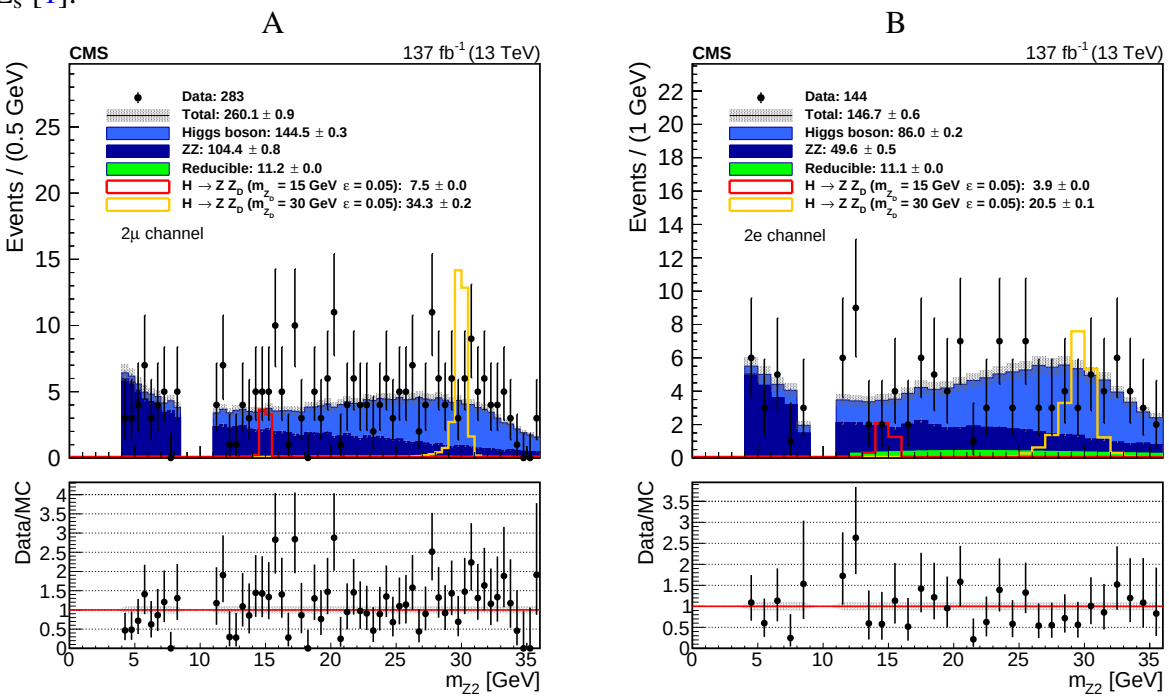
CHAPTER 1
SEARCH FOR LOW-MASS DILEPTON RESONANCES IN THE H $\rightarrow 4\ell$ CHANNEL

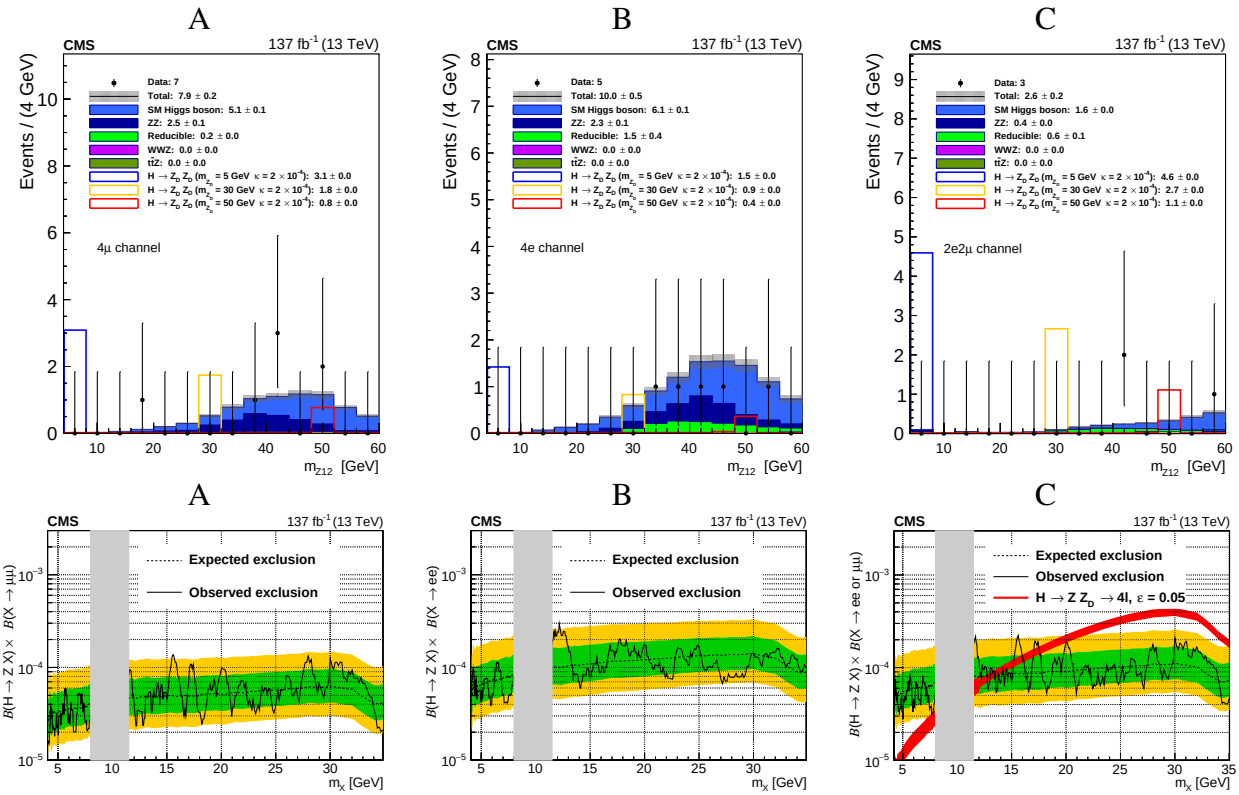
1.1 Motivation

As mentioned in Sec. **??**, even though the Higgs boson has been well studied and *appears* to be consistent with the SM Higgs boson, a single experiment that shows BSM activity (i.e., *any* deviation from SM prediction) is all that is required to completely defenestrate this idea. For example, it may be the case that the Higgs boson (H) decays into particles other than those found in the SM. This chapter details such an analysis, which follows similar topologies to the one studied in Chapter **??** ($H \rightarrow ZZ^* \rightarrow 4\ell$), specifically $H \rightarrow ZX \rightarrow 4\ell$ and $H \rightarrow XX \rightarrow 4\ell$, where X is a BSM low-mass dilepton resonance.

1.2 Results

CL_s [1].




A
B
C
CMS
137 fb-1 (13 TeV)
Events / (4 GeV)
Data: 7
Total: 7.9 ± 0.2
SM Higgs boson: 5.1 ± 0.1
ZZ: 2.5 ± 0.1
Reducible: 0.2 ± 0.0
WWZ: 0.0 ± 0.0
tt̄Z: 0.0 ± 0.0
4μ channel
Data: 5
Total: 10.0 ± 0.5
SM Higgs boson: 6.1 ± 0.1
ZZ: 2.3 ± 0.1
Reducible: 1.5 ± 0.4
WWZ: 0.0 ± 0.0
tt̄Z: 0.0 ± 0.0
4e channel
Data: 3
Total: 2.6 ± 0.2
SM Higgs boson: 1.6 ± 0.0
ZZ: 0.4 ± 0.0
Reducible: 0.6 ± 0.1
WWZ: 0.0 ± 0.0
tt̄Z: 0.0 ± 0.0
2e2μ channel
m_Z12 [GeV]
Expected exclusion
Observed exclusion
B(H → Z X) × B(X → μμ)
B(H → Z X) × B(X → ee)
B(H → Z X) × B(X → ee or μμ)
m_X [GeV]
H → Z Z_D → 4l, ε = 0.05

REFERENCES

[1] G. Cowan, K. Cranmer, E. Gross and O. Vitells, *Asymptotic formulae for likelihood-based tests of new physics*, *Eur. Phys. J. C* **71** (2011) 1554.

BIOGRAPHICAL SKETCH

Jake Rosenzweig had the best childhood anyone could ask for, growing up in Jacksonville, FL: enjoying video games with excellent friends, playing football on the beach, and having plenty of opportunity to make mistakes. He graduated from the University of Florida in 2011 with a B.S. in chemistry, while maintaining his sanity by getting minors in education and Latin. He enjoys building things from scrap, weightlifting, hiking in the Coloradoan mountains, gardening, silence, and—most of all—receiving the beleaguered stare from his wife after telling her a *particularly* bad dad joke.